THE IMPACT OF THE SAN JACONTO RIVER WASTE PITS ON THE ENVIRONMENT. PART I. ASSESSMENT OF SAN JACINTO RIVER SEDIMENT AND AQUATIC LIFE IN PROXIMITY TO THE WASTE PITS

A Preliminary Report

By Stephen King, Ph.D., M.P.H.

EXECUTIVE SUMMARY

Texans Together Education Fund (TTEF) was asked by residents living in the Channelview and Highlands, Texas area to perform a study to investigate potential environmental effects posed by the San Jacinto River Waste Pits (SJRWP) on the San Jacinto River, aquatic life, and on public health. To evaluate possible influences from the SJRWP, the TTEF collected sediment and aquatic life (fish and oyster) samples in the San Jacinto River in proximity to the SJRWP for the laboratory analysis of polychlorinated dibenzo-*para*-dioxins (PCDDs) and polychlorinated dibemzofurans (PCDFs) (PACE 2011a; PACE 2011b).

On September 14, 2011, sediments were collected in the San Jacinto River near to the SJRWP. The sediment sample collection locations are listed in Table 2. Laboratory analysis revealed that all of the sediment samples contained certain PCDD and PCDF congeners at varying concentrations (Pace 2011a). Later, on September 21, 2011, fish and one oyster sample were caught in the San Jacinto River in proximity to the SJRWP and were also found to contain PCDD and PCDF congeners at different levels (Pace 2011b). The collection locations for the fish and oyster samples are shown in Table 3.

Results of the laboratory analysis of the sediment and aquatic life samples collected by TTEF are set forth in Table 5 and Table 6, respectively. Concentrations of PCDD and/or PCDF congeners measured in the sediment samples have been found to be within ranges of PCDD and/or PCDF congeners found in samples that had been collected by the TCEQ at the SJRWP site in 2005 (ATSDR 2011). Levels of PCDD and PCDF congeners found in the aquatic life samples are in some cases near or within the ranges of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) and 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF) found in fish, crab, and/or oyster samples collected in the Houston Ship Channel at Morgan's Point and/or at the San Jacinto Monument as reported in the 1990 EPA study entitled, "Tetrachlorodibenzo-*p*-Dioxins and –Dibenzofurans in Edible Fish Tissue at Selected Sites in Arkansas, Louisiana, and Texas" (EPA 1990).

Based on the results of the study performed by TTEF that revealed the presence of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin and other dioxin-like PCDDs and PCDFs in sediment and aquatic life samples collected in the San Jacinto River in proximity to the SJRWP in September 2011, it is recommended that wading, swimming, fishing, crabbing, and collecting oysters and clams should be banned. It is strongly recommended that the consumption of fish, crabs, oysters, and clams caught in proximity to the SJRWP among vulnerable or at-risk individuals, such as pregnant women, infants, children, the elderly, persons with impaired liver function, and among individuals with an impaired immune system be prohibited. Despite the Texas Department of State Health

Services Fish and Shellfish Consumption Advisories, ADV-3 (issued in 1990) and ADV-35 (issued in 2008), healthy adults should consider not consuming any fish or shellfish caught near the SJRWP because of the likelihood that the aquatic life will contain dioxins and furans.

INTRODUCTION

Background

The San Jacinto River Waste Pits is a hazardous waste superfund site which was used for the disposal of paper mill waste (ATSDR 2011). The site is located on the western edge of the San Jacinto River a short distance north of the Interstate 10 bridge that crosses over the river between Channelview and Highlands (EPA 2012). The site was constructed sometime in late1964 or in 1965 and remained in operation until the mid-1970s (EPA 2011a; ATSDR 2011). In 1965, two waste ponds were built by constructing berms within the estuary area just north of Texas State Highway 73, which is currently Interstate 10 (EPA 2011a). The site is approximately 25 acres in size and is comprised of two waste ponds with three surface impoundments built in the 1960's (EPA 2011a). The ponds and impoundments are located on a partially submerged 20 acre parcel of land.

During its operation, the SJRWP received pulp and paper mill wastes from the Champion Paper and Fibre Company mill located on the Houston Ship Channel in Pasadena, Texas. The Champion paper mill shipped loads of waste sludge by barge for disposal in the SJRWP (ATSDR 2011). Sludge from the Champion facility was placed in two ponds on the site (EPA 2011a). The first waste pond (No. 1) is located on the western portion of the site and totals 132,386 square feet. The second waste pond (No. 2) consists of two surface impoundments, which are located on the eastern portion of the site. These two ponds total 46,182 square feet and 188,641 square feet in size (EPA 2011a). Approximately half of the surface area of the site, including the abandoned waste disposal ponds is currently submerged below the San Jacinto River water surface (EPA 2011a). Waste pond No. 1 with one impoundment is partially submerged and waste pond No. 2 with the two impoundments is completed submerged by the San Jacinto River (EPA 2011a).

In addition to shipping waste to the SJRWP, studies have shown that the Champion facility in Pasadena also shipped waste by barge for disposal at sea in the Gulf of Mexico (Hood DW 1955; Hood DW 1958; Hood DW et al 1960). Based on a study by Hood DW in 1958, a barge containing 265,000 gallons of black liquor waste from the Champion paper mill was dumped in three different locations in the Gulf of Mexico off the coast of Texas. Black liquor waste from the Champion facility has been shown to have the following characteristics: (a) specific gravity of 1.265 grams per cubic centimeter (g/cu cm) at 60° centigrade; (b) pH of 13; (c) alkalinity of 1.7 milli-equivalents per gram (meg/g); and (d) a content of 45.6% solids (Hood DW et al. 1960).

The Champion paper mill was an integrated sulfate-chlorine pulp and paper mill which used chlorine in its bleaching processes (Hoover WE et al. 1973; EPA 2012). Paper mill wastes generated from the 1950s to 1970s were known to contain high levels of polychlorinated dibenzo-*p*-

dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and other toxic substances (Stockman L et al. 1980; Rannug U et al. 1981; Houk VA 1992; Frakes RA et al. 1993; ATSDR 2011).

On September 19, 1990, the Texas Department of Health (TDH) issued a seafood consumption advisory for catfish and blue crabs caught in "The Houston Ship Channel and all contiguous waters, and upper Galveston Bay north of a line drawn from Red Bluff Point to Five Mile Cut Marker at Houston Point." The advisory was issued because elevated concentrations of dioxins in excess of 2.33 pg/g were found in fish and blue crab samples that had been routinely collected in the San Jacinto River (SJR), the Houston ship channel (HSC), and in upper Galveston Bay (UGB) (ATSDR 2011). The advisory recommended the following: (a) "No more than one meal, not to exceed eight ounces, each month;" and (b) "Women of child-bearing age and children should not consume any catfish or blue crabs from this area" (TDH 1990). The ATSDR indicated that "…the waste pits are thought to be a contributing source of the elevated levels of dioxins found in fish, crabs, and sediments in the SJR, HSC, and UGB" (ATSDR 2011). The Houston Ship Channel Toxicity Study reported in July 1995 the presence of unexplained high concentrations of dioxins were found in sediment samples that had been collected in proximity to the San Jacinto River where it flows under the Interstate 10 Bridge (ENSR 1995; ATSDR 2011a).

In 2005, the Texas Parks and Wildlife Department (TPWD) became aware of the existence of waste pits that were situated on a sandbar in the San Jacinto River just north of the Interstate 10 bridge (ATSDR 2011). Based on this information, the TPWD contacted the Texas Commission of Environmental Quality (TCEQ) in April 2005 and requested that this area be assessed by the TCEQ (ATSDR 2011b). During July and August 2005, the TCEQ collected sediment samples from the SJRWP which were analyzed for the presence of dioxin-like PCDD and PCDF congeners (ATSDR 2011b). The results of the analysis of the samples are set in Table 1, which lists the individual PCDD and PCDF congeners, with concentration ranges and averages.

The SJRWP was proposed to be placed on the EPA's National Priorities List (NPL) on September 19, 2007 (EPA 2007), and was officially added to the National Priorities List (NPL) of hazardous sites by Final Rule in 40 Code of Federal Regulations (CFR) Part 300, published in the Federal Register on March 19, 2008 (EPA 2008). The EPA in January 2010 issued its Remedial Investigation/Feasibility Study (RI/FS) work plan and initiated the field sampling sediment study, the fate and transport modeling assessment, and the bioaccumulation assessment (ATSDR 2011). Later, in April 2010, the EPA erected a fence and posted warning signs on the SJRWP in order to restrict access to the site (ATSDR 2011).

Preliminary remediation of the site was performed in 2011 with construction work on waste site cells and the central berm, and placement of geotextile and armor cap materials (A, B, C and/or D) on the cells and site (EPA 2011a; Anchor 2012a). Several EPA reports are scheduled to be released which pertain to the SJRWP, including the "Baseline Ecological Risk Assessment" report to be completed in June 2012; the "Baseline Human Health Risk Assessment" report to be completed in October 2012; the "Remedial Investigation" report to be completed in December 2012 and the "Feasibility Study" to be completed in August 2013 (EPA 2011).

Table 1

2005 San Jacinto River Waste Pits Sediment PCDD & PCDF Sampling Results[1]

PCDF/PCDD Congeners[2]	Range (Picogram/gram)	Average (pg/g)
2,3,7,8-Tetrachlorodibenzofuran	246 - 93,000	16,430.86
1,2,3,7,8-Pentachlorodibenzofuran	3.70 - 3,770	1,566.06
2,3,4,7,8-Pentachlorodibenzofuran	3.60 - 2,330	1,040.63
1,2,3,4,7,8-Hexachlorodibenzofuran	4.84 – 8,660	3,516.13
1,2,3,6,7,8-Hexachlorodibenzofuran	1.24 ND[3] – 1,390	909.83
2,3,4,6,7,8-Hexachlorodibenzofuran	1.24 ND[3] – 349	147.07
1,2,3,7,8,9-Hexachlorodibenzofuran	1.24 ND[3] – 656	281.83
1,2,3,4,6,7,8-Heptachlorodibenzofuran	1.24 ND[3] – 2,360	854.18
1,2,3,4,7,8,9-Heptachlorodibenzofuran	0.398 L[4]J[5] – 878	272.80
Octochlorodibenzofuran	390-450	420
2,3,7,8-Tetrachlorodibenzo-p-dioxin	51.2 – 23,000	8,111.89
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	1.16 L[4]J[5] – 363	177.19
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	1.24 ND[3] – 4.83	2.99
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	1.49 L[4]J[5] – 27.9	12.77
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	1.50 L[4]J[5] – 10.2	6.20
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	43.8 -658	303.26
Octachlorodibenzo-p-dioxin	1,200 – 1,200	1,200
TCDD TEQ[6] (pg/g)	81.43 -34,028	10,793.31

1 = Source: Table 5, page 70 (ATSDR 2011)
2 = Congeners of PCDDs and PCDFs (WHO 2005; Pace 2012)
3 = Not detected (ND) at the laboratory instrument detection limit (IDL)
5 = Reported concentration is between the IDL and the contract required quantitation limit (CRQL)
5 = Result is estimated
6 = TEQ(s) or toxic equivalent(s)

Current Investigation of the SJRWP

At the request of residents living near the San Jacinto River Waste Pits, Texans Together Education Fund, a 501c3 nonprofit organization, was asked to investigate the current status of potential environmental impacts from the waste pits site on the San Jacinto River, on aquatic life, and in relation to public health. To assess possible influences posed by the SJRWP, Texans Together Education Fund contracted with Houston, Texas area independent scientists to coordinate and collect sediment and aquatic life (fish and oysters) samples from the San Jacinto River in proximity to the SJRWP in order to have the samples tested for PCDDs and PCDFs.

On September 14, 2011, nine sediment samples were collected near the SJRWP. The samples were sent to Pace Analytical Services in Minnesota for the laboratory analysis of the samples for 2,3,7,8-tetrachlorodibenzo-*para*-dioxin and dioxin-like PCDDs and PCDFs. Later, on September 21, 2011, one oyster and twenty fish were caught in the San Jacinto River in proximity to the SJRWP. The oyster and tissue (fillet) samples from eight fish were sent to Pace Analytical Services for the laboratory analysis of the samples for PCDDs and PCDFs. Table 2 sets forth the locations of where the sediment samples were collected and Table 3 lists the locations of where the oyster and eight fish were caught.

Table 2
Sediment Sample Locations

Sample Number	Location
No. 1	On Bank of River - West of Site Near Fence
No. 2	On Bank of River - West of Site Halfway Between Site and Fence
No. 3	On Bank of River - Northwest Side of Site
No. 4	Near Bank of River in Water in Inlet Next to Southeast Corner of Site
No. 5	Near Bank/Shore of Northeast Side of Island in River – North/Northeast of Site
No. 6	Near Bank of River in water on East Side of Site
No. 7	South of I-10 in Kirby Marine Complex Boat Yard - East Side of Boat Yard Inlet on West Side of River
No. 8	Near West Bank of River in Water - South of Site
No. 9	Near West Bank of River in Water - Morgan's Point

ANALYSIS OF SEDIMENT, FISH, AND OSYTER SAMPLES

Results

Table 4 list the names of PCDD and PCDF congeners, abbreviations, and toxic equivalencies (TEQs) that were identified in sediment, fish, and in the oyster analyzed by Pace Analytical Services, Inc. (Pace 2011a; Pace 2011b). The results of the laboratory analysis of sediment samples are provided in Table 5 (Pace 2011a) and the results of the analysis of fish samples and the oyster are set forth in Table 6 (Pace 2011b). Concentrations of PCDD and PCDF congeners (variants or configurations of PCDD and PCDF chemical structures) found in the samples are reported in nanograms per kilogram (ng/Kg) which is equivalent to picograms per gram (pg/g) or parts per trillion.

Table 3
Aquatic Life Sample Locations

Sample Number	Description	Location
No. 1	Redfish	Just East of Waste Pits
No. 2	Redfish	Just North of Waste Pits
No. 3	Sheepshead	Just North of Waste Pits
No. 4	Flounder	South of I-10 East of the Kirby Marine Complex
No. 5	Speckled Trout	South of I-10 Next to the Kirby Marine Complex
No. 6	Redfish	South of I-10 Next to Bank of the Lynchburg Reservoir
No. 7	Speckled Trout	South of I-10 Next to Bank of the Lynchburg Reservoir
No. 8	Speckled Trout	Scott Bay
No. 9	Oyster	Burnet Bay

Table 4
PCDF and PCDD Congeners, Abbreviations, and TEQs

Congeners[1]	Abbreviations[2]	TEQ[3]
2,3,7,8-Tetrachlorodibenzo-*p*-dioxin	2,3,7,8-TCDD	1.0
1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin	1,2,3,7,8-PeCDD	1.0
1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin	1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin	1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin	1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin	1,2,3,4,6,7,8-HpCDD	0.01
Octachlorodibenzodioxin	OCDD	0.0003
2,3,7,8-Tetrachlorodibenzofuran	2,3,7,8-TCDF	0.1
1,2,3,7,8-Pentachlorodibenzofuran	1,2,3,7,8-PeCDF	0.03
2,3,4,7,8- Pentachlorodibenzofuran	2,3,4,7,8-PeCDF	0.3
1,2,3,4,7,8-Hexachlorodibenzofuran	1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-Hexachlorodibenzofuran	1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-Hexachlorodibenzofuran	1,2,3,7,8,9-HxCDF	0.1
2,3,4,6,7,8-Hexachlorodibenzofuran	2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-Heptachlorodibenzofuran	1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-Heptachlorodibenzofuran	1,2,3,4,7,8,9-HpCDF	0.01
Octochlorodibenzofuran	OCDF	0.0003

1 = Congeners of PCDDs and PCDFs (WHO 2005; EPA 2010; Pace 2012a)
2 = Abbreviations (WHO 2005; Pace 2012a)
3 = TEQ (toxic equivalency) (WHO 2005; EPA 2010; Pace 2011a; DioxinFacts 2012.)

Table 5 sets forth the PCDD and PCDF congeners which were identified in the sediment samples. Polychlorinated dibenzofuran congeners found in sediment samples, along with their respective concentrations and ranges are as follows: (a) 2,3,7,8-tetrachlorobenzofuran (2,3,7,8-TCDF or TCDF), range: not detected (ND) to 78.00 ng/Kg; (b) total TCDF, range: ND to 140.00 ng/Kg; (c) 1,2,3,7,8-pentachlorodibenzofuran (1,2,3,7,8-PeCDF), range: ND to 1.50 ng/Kg; (d) 2,3,4,7,8-pentochlorodibenzofuran (2,3,4,7,8-PcCDF), range: ND to 3.10^{J}; (e) total pentachlorodibenzofurans (PeCDF), range: ND to 45.00 ng/Kg; (f) 1,2,3,4,7,8-hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF), range: ND to 3.00^{J} ng/Kg; (g) 1,2,3,6,7,8-hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF), range: ND to 1.60^{J} ng/Kg; (h) 2,3,4,6,7,8-hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF), range: ND to 1.40^{J} ng/Kg; (i) 1,2,3,7,8,9-hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF), findings: ND or interference present in all samples); (j) total hexachlorodibenzofurans (HxCDF), range: ND to 23.00 ng/Kg; (k) 1,2,3,4,6,7,8-heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF), range: ND to 13.00 ng/Kg; (l) 1,2,3,4,7,8,9-heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF), range: ND to 2.00^{J} ng/Kg; (m) total heptachlorodibenzofurans (HpCDF), range: ND to 38.00 ng/Kg; and (l) octchlotrodibenzofuran (OCDF), range: ND to 36.00 ng/Kg)(Pace 2011a).

Polychlorinated dibenzo-*p*-dioxin congeners identified in sediment samples, along with their respective concentrations and ranges are as follows: (a) 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), range: ND to 17.00 ng/Kg; (b) total tetrachlorodibenzo-*p*-dioxin (TCDD), range: ND to 42.00 ng/Kg; (c) 1,2,3,7,8-pentachlorodibenzo-*p*-dioxin (1,2,3,7,8-PeCDD), range: ND to 0.74 ng/Kg; (d) total pentachlorodibenzo-*p*-dioxin (PeCDD), range: ND to 51.00 ng/Kg; (e) 1,2,3,4,7,8-hexachlorodibenzo-*p*-dioxin (1,2,3,4,7,8-HxCDD), range: ND to 1.00^{J} ng/Kg; (f) 1,2,3,6,7,8- hexachlorodibenzo-*p*-dioxin (1,2,3,6,7,8-HxCDD), range: ND to 3.30^{J} ng/Kg; (g) 1,2,3,7,8,9 hexachlorodibenzo-*p*-dioxin (1,2,3,7,8,9-HxCDD), range: ND to 1.40^{J} ng/Kg; (h) total hexachlorodibenzo-*p*-dioxins (HxCDD), range: ND to 47.0 ng/Kg; (i) 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin (1,2,3,4,6,7,8-HpCDD), range: 0.42^{J} ng/Kg to 66.00 ng/Kg; (j) total heptachlorodibenzo-*p*-dioxin (HpCDD), range: 0.42^{BJ} ng/Kg to 170 ng/Kg; (k) octachlorodibenzo-p-dioxin (OCDD), range: 20 ng/Kg to 720 ng/Kg; and (l) total 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) equivalence, range 0.0042 ng/Kg to 25.0 ng/Kg (Pace 2011a).

Of the nine sediment samples that were tested for polychlorinated dibenzodioxins and polychlorinated dibenzofurans, sample No. 8 had the least number of different dioxin and furan congeners present in the samples. Specifically, 1,2,3,4,6,7,8-hepta-chlorodibenzo-*p*-dioxin was the only PCDD or PCDF congener found in the sample. Sample No. 7 had the greatest number of different dioxin and furan congeners identified in the samples. In consideration of the toxicity of the various PCDD and PCDF congeners, sample No. 4 had the highest concentration of the most toxic congener, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin or TCDD, with 17.00 ng/Kg present in the sample. Sample No. 9 had the highest level of total TCDD at 42.00 ng/Kg and sample 4 had the highest TCDD equivalence at 25.00 ng/Kg. Sample No. 5 was found to have had only two PCDD or PCDF congeners, 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin and octochlorodibenzodioxin.

Table 5
Laboratory Results for Sediment Samples

Congeners	Sample Numbers and Concentrations[1] (ng/Kg)								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
2,3,7,8-TCDF	12.00	8.00	3.30	78.00	ND	61.00	15.00	ND	ND
Total TCDF	14.00	11.00	5.30	140.00	ND	120.00	28.00	ND	61.00
2,3,7,8-TCDD	2.70	2.00	0.74[J]	17.00	ND	13.00	4.10	ND	ND
Total TCDD	2.70	2.00	0.74[J]	19.00	ND	14.00	5.10	ND	42.00
1,2,3,7,8-PeCDF	-----[I]	ND	ND	-----[I]	ND	1.50	1.40[J]	ND	ND
(2,3,4,7,8-PeCDF	-----[I]	ND	ND	1.40[J]	ND	1.30	-----[P]	ND	3.10[J]
Total PeCDF	ND	ND	ND	2.30[J]	ND	3.80	13.00	ND	45.00
1,2,3,7,8-PeCDD	ND	ND	ND	ND	ND	-----[I]	0.74	ND	-----[I]
Total PeCDD	ND	ND	ND	ND	ND	0.40[J]	2.30	ND	51.00
1,2,3,4,7,8-HxCDF	0.90[J]	0.69[J]	ND	2.00[J]	ND	1.50[J]	3.00[J]	ND	1.10[BJ]
1,2,3,6,7,8-HxCDF	-----[I]	ND	ND	-----[I]	ND	0.84[J]	1.60[J]	ND	-----[P]
2,3,4,6,7,8-HxCDF	ND	ND	ND	ND	ND	0.46[J]	1.40[J]	ND	-----[I]
1,2,3,7,8,9-HxCDF	ND	ND	ND	ND	ND	-----[I]	-----[I]	ND	ND
Total HxCDF	1.50[J]	0.69[J]	ND	2.20[J]	ND	4.10[J]	23.00	ND	15.0
1,2,3,4,7,8-HxCDD	ND	ND	ND	ND	ND	ND	1.00[J]	ND	ND
1,2,3,6,7,8-HxCDD	ND	ND	ND	ND	ND	ND	2.50[J]	ND	3.30[J]
1,2,3,7,8,9-HxCDD	ND	ND	ND	ND	ND	ND	1.40[J]	ND	-----[I]
Total HxCDD	2.20[J]	ND	0.47[J]	1.40[J]	0.49[J]	4.70[J]	33.00	ND	47.00
1,2,3,4,6,7,8-HpCDF	-----[I]	1.10[J]	-----[I]	-----[I]	-----[I]	1.10[J]	13.00	ND	4.80[J]
1,2,3,4,7,8,9-HpCDF	ND	ND	ND	ND	ND	ND	2.00[J]	ND	-----[I]
Total HpCDF	0.56[J]	1.10[J]	ND	ND	ND	1.10[J]	38.00	ND	7.20
1,2,3,4,6,7,8-HpCDD	2.80[J]	8.40	1.50[J]	1.54[J]	-----[I]	6.80	66.00	0.42[J]	12.00
Total HpCDD	8.60	25.00	3.90[J]	4.30[J]	2.30[J]	25.00	170.00	0.42[BJ]	12.00
Octochlorodibenzofuran	1.10[J]	5.70[J]	-----[I]	0.70[J]	-----[I]	3.00	36.00	ND	2.10
Octachlorodibenzodioxin	45.00	140.00	23.00	32.00	20.00	130.00	720.00	-----[I]	62.00
Total 2,3,7,8-TCDD Equivalence[3]	4.00	3.10	1.10	25.00	0.020	20.00	8.70	0.0042	2.20

1 = Totals include 2,3,7,8-TCDD substituted isomers
2 = ng/Kg is nanograms per kilogram
3 = 2,3,7,8-TCDD Equivalence using ITE Factors
ITE = International TCDD Equivalents
TCDD = Tetrachlorodibenzo-*p*-dioxin
B = Less than 10 times higher than method blank levels
I = Interference present
J = Estimate value
ND = Not Detected
P = PCDE interference
PCDE = Polychlorinated diphenyl ether

Table 6
Laboratory Results for Aquatic (Fish and Oyster) Samples

Congeners	Sample Numbers and Concentrations[1] (ng/Kg)[2]								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
2,3,7,8-TCDF	0.20[J]	-----[I]	0.70	0.96	1.30	7.20	1.20	0.40[J]	4.10
Total TCDF	0.32[J]	ND	0.70	0.96	1.30	7.20	1.20	0.40[J]	9.60
2,3,7,8-TCDD	ND	ND	0.93	1.20	0.51	2.90	0.34[J]	0.11[J]	1.10
Total TCDD	ND	ND	0.93	1.20	0.51	2.90	0.34[J]	0.11[J]	2.20
1,2,3,7,8-PeCDF	ND	ND	ND	ND	0.19[J]	0.55[J]	0.12[J]	ND	0.16[J]
2,3,4,7,8-PeCDF	ND	ND	0.08[J]	ND	ND	0.36[J]	ND	ND	0.14[J]
Total PeCDF	ND	ND	0.08[J]	ND	0.19[J]	1.10[J]	0.12[J]	ND	0.81[J]
1,2,3,7,8-PeCDD	ND	0.34[J]	ND	0.15[J]	ND	0.35[J]	ND	ND	ND
Total PeCDD	ND	0.34[J]	ND	0.15[J]	ND	0.35[J]	ND	ND	0.25[J]
1,2,3,4,7,8-HxCDF	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,3,6,7,8-HxCDF	-----[P]	-----[P]	-----[I]	-----[P]	-----[P]	-----[P]	-----[P]	-----[P]	ND
2,3,4,6,7,8-HxCDF	ND	ND	ND	ND	ND	ND	ND	ND	0.11[J]
1,2,3,7,8,9-HxCDF	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total HxCDF	ND	ND	ND	ND	ND	ND	ND	0.12[J]	0.65[J]
1,2,3,4,7,8-HxCDD	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,3,6,7,8-HxCDD	ND	ND	ND	ND	ND	0.35[J]	ND	ND	ND
1,2,3,7,8,9-HxCDD	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total HxCDD	ND	ND	ND	ND	ND	0.35[J]	ND	ND	130.00[J]
1,2,3,4,6,7,8-HpCDF	0.13[J]	0.84[J]	-----[I]	-----[I]	0.40[J]	2.10[J]	-----[I]	-----[P]	-----[I]
1,2,3,4,7,8,9-HpCDF	ND	-----[I]	ND	ND	ND	ND	ND	ND	ND
Total HpCDF	0.13[J]	0.84[J]	ND	ND	0.40[J]	2.10[J]	ND	ND	ND
1,2,3,4,6,7,8-HpCDD	-----[I]	0.37[J]	ND	0.18[J]	0.16[J]	0.19[J]	ND	ND	-----[I]
Total HpCDD	0.14[BJ]	0.37[BJ]	ND	0.30[BJ]	0.31[J]	0.32[BJ]	0.13[BJ]	0.20[BJ]	2.00
Octochlorodibenzofuran	ND	-----[I]	ND	ND	ND	ND	ND	ND	0.68[J]
Octachlorodibenzodioxin	-----[I]	1.70[J]	-----[I]	0.66	0.68[J]	0.94[J]	0.35[J]	0.91[J]	14.00
Total 2,3,7,8-TCDD Equivalence[3]	0.021	0.18	1.00	1.30	0.65	4.00	0.47	0.15	1.60

1 = Totals include 2,3,7,8-TCDD substituted isomers
2 = ng/Kg is nanograms per kilogram
3 = 2,3,7,8-TCDD Equivalence using ITE Factors
ITE = International TCDD Equivalents
TCDD = Tetrachlorodibenzo-*p*-dioxin
B = Less than 10 times higher than method blank levels
I = Interference present
J = Estimate value
ND = Not Detected
P = PCDE interference
PCDE = Polychlorinated diphenyl ether

The PCDD and PCDF congeners identified in the oyster and fish samples are listed in Table 6. Polychlorinated dibenzofuran congeners found in the oyster and fish samples, along with their respective concentrations and ranges are as follows: (a) 2,3,7,8-chlorodibenzofuran (2,3,7,8-TCDF or TCDF), range: 0.20^{J} to 7.20 ng/Kg; (b) total TCDF, range: ND to 7.20 ng/Kg; (c) 1,2,3,7,8-(1,2,3,7,8-PeCDF), range: ND to 0.55^{J} ng/Kg; (d) 2,3,4,7,8-pentachlorodibenzofuran (2,3,4,7,8-PeCDF), range: ND to 0.36^{J} ng/Kg; (e) total pentachlorodibenzofurans (PeCDF), range: ND to 45.00 ng/Kg; (f) 1,2,3,4,7,8-hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF), range: ND to 3.00 ng/Kg; (g) 1,2,3,6,7,8-hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF), range: ND to 0.35^{J} ng/Kg; (h) 2,3,4,6,7,8-hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF), range: ND to 0.11^{J} ng/Kg; (i) 1,2,3,7,8,9-hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF), findings: ND in all samples); (j) total hexachlorodibenzofurans (HxCDF), range: ND to 0.65^{J} ng/Kg; (l) 1,2,3,4,6,7,8-heptachloro-dibenzofuran (1,2,3,4,6,7,8-HpCDF), range: 0.13^{J} to 2.10^{J} ng/Kg; (l) 1,2,3,4,7,8,9-heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF), range: ND or interference in all samples; (m) total heptachlorodibenzofurans (HpCDF), range: ND to 2.10^{J} ng/Kg; and (m) octchlotrodibenzofuran (OCDF), range: ND to 0.68^{J} ng/Kg (Pace 2011b).

Of the nine aquatic life samples that were tested for polychlorinated dibenzodioxins and polychlorinated dibenzofurans, 1,2,3,4,7,8-HxCDD, 1,2,3,7,8,9-HXCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, and 1,2,3,7,8,9-HxCDD were not detected in any of the samples. The PCDF congener, 1,2,3,6,7,8-HxCDF, was not detected in sample No.9 and was not reported to have been present in any of the remaining samples (Nos. 1-8) due to interference with polychlorinated diphenyl ether (PCDE). Also, the PCDF congener, 1,2,3,4,7,8,9-HpCDF, was not detected in samples 1 and 3-9, and was not reported to have been present in sample No. 2 due to interference with polychlorinated diphenyl ether.

Sample No. 1 had the least number of detected PCDD and PCDF congeners. Sample No. 9, the oyster sample, was found to have the most detected number of PCDD and PCDF congeners. With respect to the toxicity of the various PCDD and PCDF congeners, sample No. 9 had the highest concentration of the most toxic congener, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin or TCDD, with 2.90 ng/Kg present in the sample. Sample No. 9 also had the highest total 2,3,7,8-TCDD (2.20 ng/Kg) concentration and the highest total 2,3,7,8-TCDD equivalence (1.60 ng/Kg) among all of the nine aquatic samples.

PULP AND PAPER MILL EFFLUENTS AND WASTE

Effluents from pulp and paper mills have been shown to contain dissolved lignin, cellulose degradation products, other wood extractives, and chlorinated compounds derived from the bleaching process (Houk VA 1992). In addition to dioxins and furans, approximately 300+ chemical compounds have been identified as constituents of pulp and paper mill effluents and waste (Houk VA 1992; Lee EGH et al. 1978). Among these chemicals compounds, are carcinogens, mutagens, and teratogens. Table 7 lists certain toxic substances that have been identified in pulp and paper mill effluents and waste.

Table 7
Toxic Substances Identified in Pulp and Paper Mill Effluents and Waste

Substances

Acetovanillone
Benzyl Chloride
Bromocymene
Bromodichloromethane
3-Chloro-4-dichloromethyl-5-hydroxy-2(5H)-furanone (MX)
Chloromuconic Acid
2-Chloropropenal
Dibromochloromethane
1,3-Dichloroacetone
Dichlorocatechol
Dichloro-p-cymene
1,2-Dichloroethane
Dichloroguaiacol
1,2-Dichloromethane
Hexachloroacetone
Monochloroacetaldehyde
Neoabietic Acid
1-Oxa-6,7,10,10-tetra-chlorospiro(4.5)dec-6-en-8,9-dione
1-Oxa-6,10,10-trichlor-spiro(4.5)dec-6-en-8,9-dione
7-Oxydehydroabietic Acid
Pentachloroacetone
Pentachloropropene
Polychlorinated dibenzo-para-dioxins
Polychlorinated dibenzofurans
1,1,3,3-Tetrachloroacetone
2,3,7,8-Tetrachlorodibenzo-para-dioxin
1,1,2,2-Tetrachloroethane
Tetrachloroethylene (Perchloroethyelene)
Tetrachloropropene
Trichloroacetaldehyde
1,1,3-Trichloroacetone
1,1,1-Trichloroethane
Trichloroethylene
1,2,3-Trihydroxybenzene

Source: (Stockman L et al. 1980; Rannug U et al. 1981; Kringstad KP and Lindstrom K 1984; Moller MA 1986; Houk VA 1992; Frakes RA et al. 1993; ATSDR 2011)

The chemicals responsible for the genotoxic activity of pulp and paper mill effluent are almost exclusively low-molecular-weight, chlorinated compounds (Stockman L et al. 1980; Rannug U et al. 1981; Kringstad KP and Lindstrom K 1984; Moller MA 1986). Both hydrophilic (water-soluble) and lipophilic (ether and fat soluble) mutagens have been isolated and identified in pulp and paper mill effluents. Most of the mutagenic activity has been found in the lipophilic ether fraction (Ander R et al. 1977; Stockman L et al. 1980; Rannug U et al. 1981). The most predominant lipophilic mutagens are the neutral compounds, such as the chloroacetones and other chlorinated aliphatic substances. Hydrophilic mutagens include resin acids and phenolic compounds, such as chlorinated catechols and guaiacols (Houk VA 1992). Some of the toxic substances present in pulp and paper mill effluents are not readily degradable and may persist in the environment and bioaccumulate (Houk VA 1992). Studies by Stockman et al (1980) and Kringstad et al. (1984) have demonstrated that the mutagenicity of the chlorination-stage effluent could be detected after long periods of storage. Kringstad et al. (1984) attributed the mutagenic activity and persistence of the compounds with their high degree of lipid solubility, which could result in their accumulation in the food-chain. Even though chlorinated phenols are hydrophilic in nature, they tend to be persistent and have been found to bioaccumulate in fish (Landner L et al. 1977; Paasivirta J et al. 1980).

Studies of plants and animals located in proximity to pulp and paper mills have provided evidence of the genotoxic effects of pulp and paper mill effluents and waste (Klekowski EJ and Berger BB 1976; Klekowski E and Levin De 1979; Blevins RD 1991). For example, a fern population (Osmunda regalis) that was found growing downstream from the outfalls of a pulp and paper mill was shown to have a high incidence of chromosome mutations (Klekowski EJ and Berger BB 1976; Klekowski E and Levin De 1979). Tissue extracts obtained from various fish species collected from a river highly contaminated with discharges from a kraft pulp bleaching paper mill exhibited significant mutagenic activity when tested in the Salmonella assay (Blevins RD 1991). The incidence of cancerous disease in spotted sea trout caught in bay waters heavily impacted by pulp mill operations was 50.4% (Kinae N et al. 1981a). The same researchers tested liver extracts from the sea trout and found that livers from tumor-bearing fish contained compounds that can cause DNA damage in B. subtilis and mutations in Salmonella (Kinae N 1981b). In a later study, Das and Nanda, (1986) reported a significant increase in the incidence of micronuclei in erythrocytes of catfish exposed in the laboratory to a paper mill effluent that had been collected prior to its discharge. Compared to other industries, the chlorination stage effluent produced by kraft pulp and paper mills demonstrated a high mutagenic potential based on activity per unit volume of the effluent discharged from the facilities (Houk VA 1992).

Frankes RA et al. (1993) assessed the bioaccumulation of 2,3,7,8-tetrachlorodibenzo-p-dioxin or TCDD by fish downstream from pulp and paper mills in Maine. Dioxin levels in tissues of predatory and bottom feeding species of fish were collected from Maine's major water bodies, including five rivers which received bleached kraft paper mill effluents. Also, data on dioxin concentrations in the effluent of the mills were evaluated in the study. Monitoring results were analyzed by using simple models to produce "field bioaccumulation factors" (BAFs) for TCDD in rivers in Maine (Frakes RA et al. 1993). Based on this study, some of the highest levels of TCDD

BAFs were found in fish collected from the Kennebec River at Fairfield, Maine (Frakes RA et al. 1993).

DISCUSSION

A previous on-site assessment of the San Jacinto River Waste Pits in 2005 found high concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, as well as other polychlorinated dibenzodioxin and/or dioxin-like polychlorinated dibenzofuran congeners in sediment samples (ATDSR 2011). Table 1 sets forth the concentrations of TCDD, and dioxin-like PCDD and PCDF congeners identified in the samples, along with the average PCDD and PCDF congener concentrations for all of the sediment samples tested. The highest concentration of the carcinogenic PCDD, 2,3,7,8-tetrachlorodibenzo-*para*-dioxin, was 23,000 pg/g, which was found in an on-site sediment sample collected by the TCEQ at approximately 1-6 inches below soil/sediment surface (ATSDR 2011).

Analysis of sediment samples collected on September 14, 2011, revealed that the highest concentration of 2,3,7,8-TCDD was found in sample No. 4., and was at a level of 17 ng/Kg. Sample No. 4 was a grab sample that was collected under water on the surface of sediment in the San Jacinto River in an inlet next to the southeast corner of the SJRWP (Pace 2011a). The highest 2,3,7,8-TCDD TEQ or toxic equivalence was also found in sediment sample No. 4 and was 25.0 ng/Kg (Pace 2011a).

TCDD TEQ concentrations for samples collected in 2005 on the SJRWP and at locations down river from the waste site were reported in the ATSDR Public Health Assessment (ATSDR 2011). A TEQ or toxic equivalent is used to report the toxicity-weighted masses of mixtures of dioxins and/or dioxin-like furans (DioxinFacts 2012). Each dioxin and dioxin-like furan compound is assigned a toxic equivalency factor (TEF) TCDD (WHO 2005; Pace 2011a; DioxinFacts 2012). The factor denotes a given dioxin and/or dioxin-like furan compound's toxicity relative to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD or TCDD) which is assigned the maximum toxicity designation of one (1) . Other dioxin and/or dioxin-like furan compounds are given equal or lower numbers, with each number roughly proportional to its toxicity relative to that of 2,3,7,8-TCDD (WHO 2005; Pace 2011a; DioxinFacts 2012).

Set forth are the TEQs for locations reported in the ATSDR assessment: (a) on-site samples at the SJRWP, range: 80.92 pg/g to 34,028 pg/g, with an average of 15,594 pg/g; (b) down-stream from the SJRWP, San Jacinto River, Houston Ship Channel, and Upper Galveston Bay, range: 0.739 pg/g to 86.16 pg/g, with an average of 13.75 pg/g; (c) SJRWP site vicinity and San Jacinto River near the SJRWP, range: 1.997 pg/g to 572.5 pg/g, with an average of 82.24 pg/g; (d) Houston Ship Channel and above, and west of the San Jacinto River, range: 4.904 pg/g to 856.8 pg/g, with an average of 65.69; (e) up-stream and tributaries to the San Jacinto River, Houston Ship Channel, and Upper Galveston Bay, range: 0.759 pg/g to 102.9 pg/g, with an average of 15.97; and (f) All off-site samples, range: 0.739 pg/g to 856.8 pg/g, with an average of 40.04 pg/g (ATSDR 2011).

The reported TCDD TEQs for the nine sediment samples collected on September 14, 2011, and the subject of this report, ranged from 0.0042 ng/Kg to 25.00 ng/Kg (Pace 2011a). In some cases the reported TCDD TEQs found in the sediment samples collected on September 14, 2011, were above the minimum TCDD TEQ concentrations found by the TCEQ in 2005 for all off-site sample locations as reported in the ATSDR Public Health Assessment (ATSDR 2011).

The identification of polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans in on-site sediment samples collected at the SJRWP in 2005 (ATSDR 2011) confirmed that the SJRWP site has been contaminated with elevated concentrations of PCDDs and PCDFs. The presence of PCDDs and PCDFs in surficial sediment samples collected on September 14, 2011 in proximity to the SJRWP demonstrate that sediment in the San Jacinto River and on the banks of the river continue to be contaminated with PCDDs and PCDFs (Pace 2011a).

One oyster and eight fish caught in the San Jacinto River on September 21, 2012 were all found to contain measurable concentrations of some PCDD and PCDF congeners (Pace 2011b). Sample 6 (redfish) had the highest concentration of 2,3,7,8-tetrachloro- dibenzo-*p*-dioxin of 2.90 ng/Kg and the highest total TCDD concentration of 2.90 pg/Kg. The highest 2,3,7,8-TCDD TEQ concentration (4.00 pg/Kg) was also found in aquatic sample No. 6 (redfish) (Pace 2011b). Aquatic sample No. 9 (oyster) had the highest concentration of 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF) of 4.10 ng/kg and the highest total 2,3,7,8-TCDF of 9.60 ng/Kg. The total concentration of a specific PCDD or PCDF congener identified in an aquatic life ample caught in the San Jacinto River was 130.0^{J} ng/Kg and was found in the oyster.

Overall, the principle toxic substances that have been documented at the SJRWP are polychlorinated dibenzo-*para*-dioxins and polychlorinated dibenzofurans (ATSDR 2011). Based on passed investigations performed at the SJRWP, according to the EPA (EPA 2011a), concentrations of dioxins as high as 41,300 parts per trillion (ppt) were found in sediment samples collected from the disposal pond areas on the site and in river sediments near the site. Sediment samples collected from the submerged portion of the waste disposal ponds were shown to have dioxin concentrations as high as 360,000 ppt organic carbon normalized (EPA 2011a). Sediment samples collected outside the original 1966 berm placement for the two waste ponds had dioxin concentrations up to 3,660 ppt action level which was indicative of dioxin being released from the original location of the waste ponds (EPA 2011a).

CONCLUSIONS

The fact that measurable concentrations of PCDDs and PCDFs were found in both San Jacinto River sediment and in aquatic life samples collected in the river near the San Jacinto River Waste Pits in September 2011 strongly suggests that the waste pits have been and are still a source of dioxin and furan contamination of the San Jacinto River. This conclusion is in agreement with the view of the Texas Department of Health as cited in the ATDSR Public Health Assessment, which stated, "…the waste pits are thought to be a contributing source of the elevated levels of dioxins found in fish, crabs, and sediments in the SJR, HSC, and UGB." The "SJR", "HSC", and "UGB", represents the San Jacinto River, the Houston Ship Channel, and the Upper Galveston Bay,

respectively. The discovery of dioxin concentrations as high as 360,000 ppt (EPA 2011a) approximately 40 years after the site was created demonstrates that the SJRWP is an exceeding hazardous and toxic site.

Wading, swimming, fishing, crabbing, and collecting oysters and clams in the San Jacinto River in proximity to the San Jacinto Waste Pits should be banned. Consumption of fish, crabs, oysters, and clams caught in proximity to the SJRWP among vulnerable or at-risk populations, such pregnant women, infants, children, the elderly, persons with impaired liver function, and among individuals with an impaired immune system should be prohibited. Even though the Texas Department of State Health Services promulgated Fish and Shellfish Consumption Advisories, ADV-3 (issued in 1990) and ADV-35 (issued in 2008), healthy adults should consider not consuming any edible fish or shellfish caught in the San Jacinto River near the SJRWP because of the likelihood that the aquatic life will contain dioxins and furans.

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